WINTER CYCLOGENESIS WITH TROPICAL CHARACTERISTICS OVER THE GULF STREAM

CADESMAN POPE, JR.

National Meteorological Center, Weather Bureau, ESSA, Suitland, Md.

ABSTRACT

An extratropical cyclone associated with the subtropical jet stream and the interaction of continental polar and maritime tropical air masses originated in the subtropics and moved northeastward off the East Coast of the United States. The storm moved first parallel to, and then briefly over the center of the Gulf Stream. As it moved over the warmest water of the Gulf Stream, its inner core appeared on radar to be similar to a tropical cyclone. There was a strong correlation between the radar banding and weather resembling that experienced in the spiral bands of hurricanes.

1. INTRODUCTION

During the 60-hr. period from 0000 GMT, Feb. 6 to 1200 GMT, Feb. 8, 1968, a unique winter cyclone developed off the east coast of the United States. It reached hurricane strength, which is not too infrequent in that area of the Atlantic at that time of year. However, as a strongly developing extratropical cyclone, it moved over the Gulf Stream near Cape Hatteras, N.C., and for a short time displayed characteristics of a storm whose inner core resembled that of a tropical cyclone.

2. DESCRIPTION OF THE STORM DEVELOPMENT

On the evening of February 5 (0000 GMT, Feb. 6, 1968), a weak polar front stretched westward from the west-central Atlantic through the Bahamas into the lower east coast of Florida (fig. 1). At this time, cloudiness and scattered showers were occurring over southern Florida and in an area over the Gulf Stream from east of Florida, north to the latitude of South Carolina. The surface pressure pattern showed a weak inverted trough east of Florida, extending northeastward from central Cuba to near 31°N. and 75°W. A continental polar high pressure center was located just west of Chicago, Ill., and over extreme eastern North Carolina.

In the middle troposphere, a maximum of vorticity was located just southwest of Memphis, Tenn. (fig. 2). Upper air observations, at this time, indicated a moderately strong jet stream near 200 mb. over central Florida (fig. 3).

By 1200 GMT, February 6, the weak polar front was no longer discernible at the surface. In the already existing inverted trough east of Florida a northward moving low pressure center had developed in response to the east-southeastward moving upper trough over Alabama. Radar reports located most shower activity east of the Florida peninsula—apparently over the Gulf Stream. Scattered thundershowers were detected by radar in the precipitation area over water.

An ESSA-3 satellite picture taken at 1640 GMT, February 6 (fig. 4) showed two distinct cloud masses in the lower East Coast area; one was over northern Florida, while a larger mass was centered near 28°N. and 75°W. This picture was in reasonable agreement with the surface position of the Low (see track, fig. 5). The dense cloudiness in the vicinity of the Low was associated with considerable precipitation corroborated by 0.40-in. measured at Great Bahama Island at 1200 GMT and 1.09 in. at 1800 GMT.

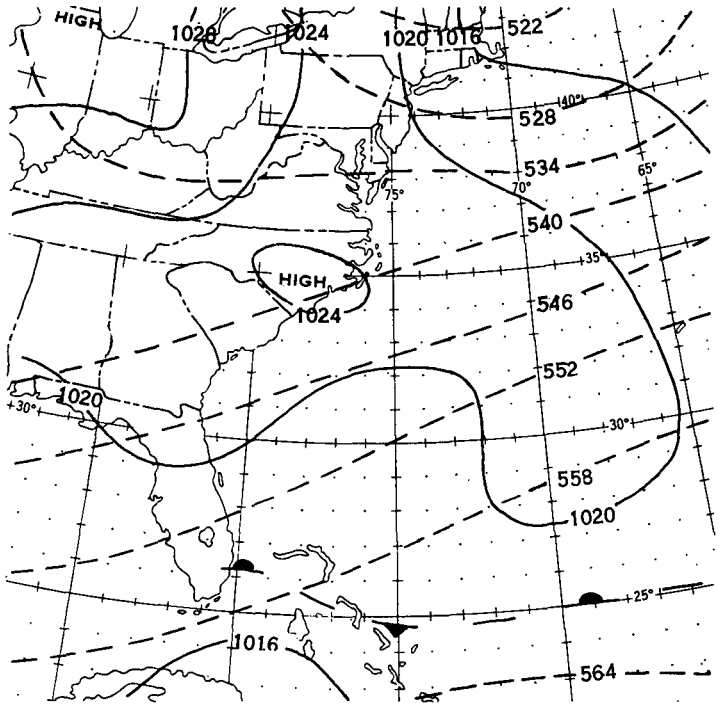

FIGURE 1.—Surface chart with isobars (solid) in millibars and with 1000–500-mb. thickness lines (dashed) in thousands of meters for 0000 GMT, Feb. 6, 1968.

At the surface, the Low near Great Bahama Island had moved north-northeastward to near 30°N. and 77°W. and deepened 4 mb. by 0000 GMT, February 7 (fig. 6). The 1000–500-mb. thickness field with this Low indicated a frontal wave had already developed north of the Bahamas by 0000 GMT. The continental polar ridge of high pressure in the Mid-Atlantic States had broken down rapidly.

The vorticity maximum over southwestern Alabama had moved east-southeastward to extreme northern Florida (fig. 7) with positive vorticity advection over the area of the Low north of the Bahamas. Cloudiness had

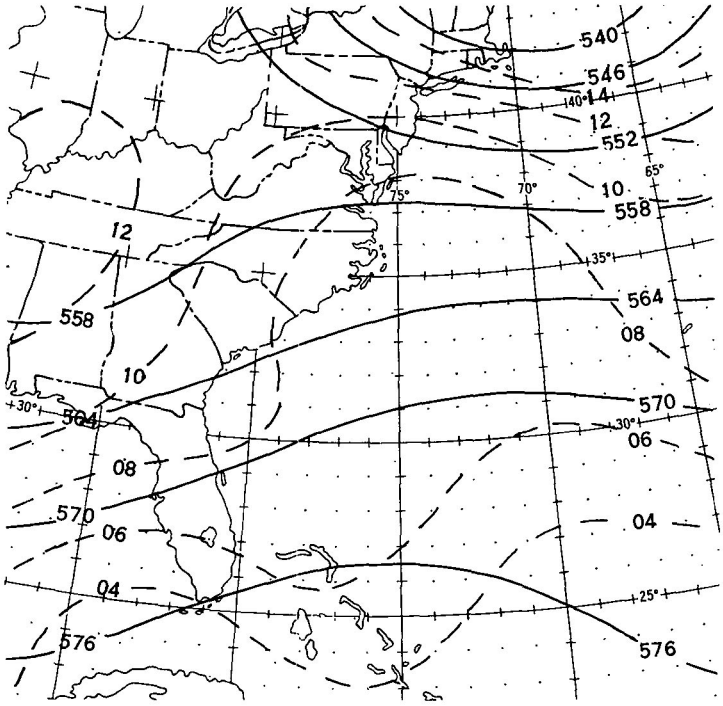

FIGURE 2.—500-mb. contours (solid) in decameters with isopleths of absolute vorticity (dashed) in radians $\times 10^{-5}$ sec.$^{-1}$ for 0000 GMT, Feb. 6, 1968.

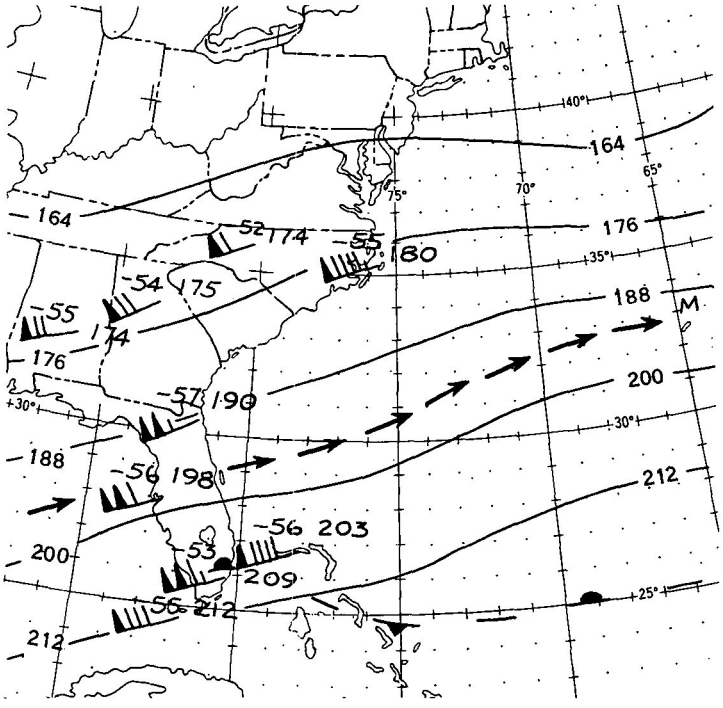

FIGURE 3.—200-mb. contours (in decameters) and jet stream (heavy arrows) for 0000 GMT, Feb. 6, 1968, with surface fronts superimposed.

moved into the coastal sections of the Carolinas and rain was observed along the entire South Carolina coastline and much of the southeastern coastal area of North Carolina.

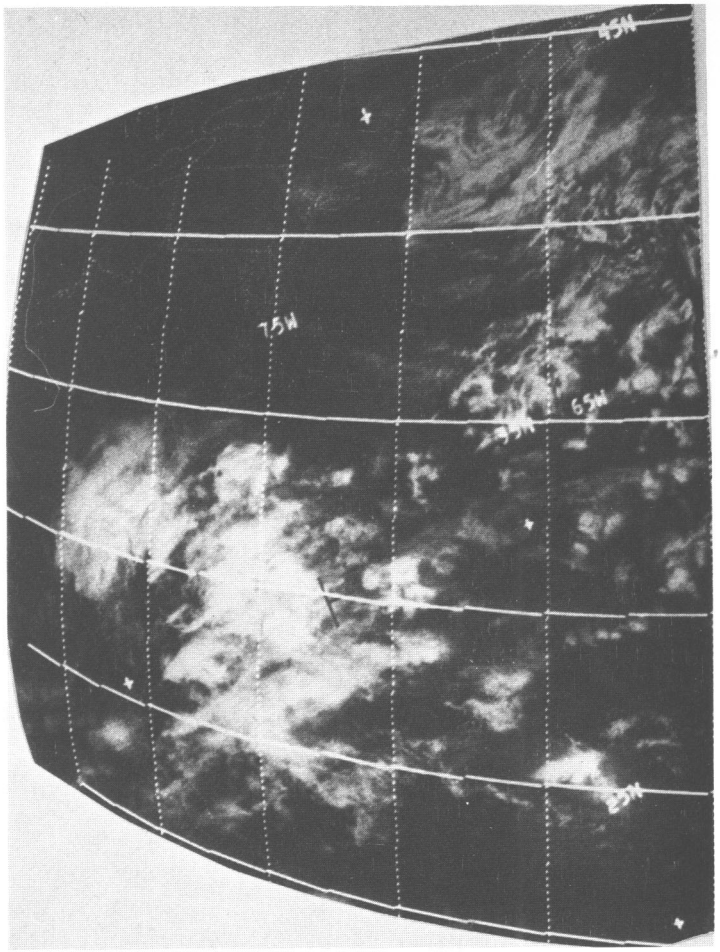

FIGURE 4.—ESSA-3 photograph of United States East Coast and Atlantic Ocean east to 60°W., taken at 1640 GMT, Feb. 6, 1968.

At 200 mb. (fig. 8), the subtropical jet over Florida had remained about the same intensity and moved southward.

Within the next 24 hr., some remarkable developments ensued. At 1200 GMT, February 7, the surface Low was near 33°N. and 75°W. The surface Low deepened 18 mb. in 12 hr. when the strong midtropospheric trough and the surface Low became juxtaposed. Possibly, the addition of sensible heat over the warm Gulf Stream (fig. 5) contributed to deepening. Also, the addition of latent heat of condensation must have been a factor. Rainfall and cloudiness in connection with the Low were observed over the southeastern coastal area of North Carolina with a cloud shield (fig. 9) extending northward along the coastal areas of Virginia, Maryland, and Delaware.

An ESSA-6 satellite photograph taken at 1500 GMT, February 7 (fig. 9), showed the structure of an occluding cyclone with dense cloud to the north and east of the occlusion and cold front. Cyclonic circulation was discernible in the dense cloud near the low center (near

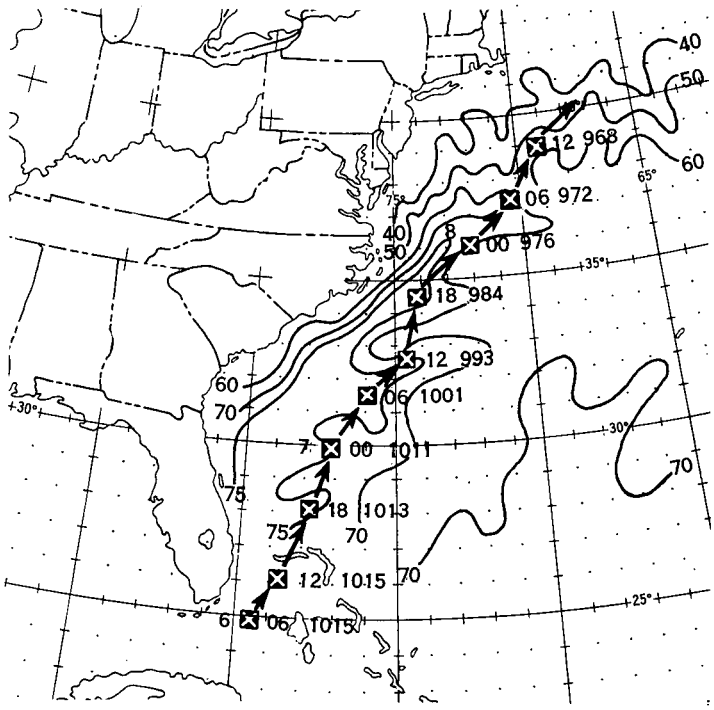

FIGURE 5.—6-hr. track of Low from 0600 GMT, Feb. 6, 1968, through 1200 GMT, Feb. 8, 1968. Track superimposed on sea-surface isotherms (in °F.) for February 7. The day is to the left and the time (GMT) and central pressure (mb.) to the right of the positions (crosses) of the Low.

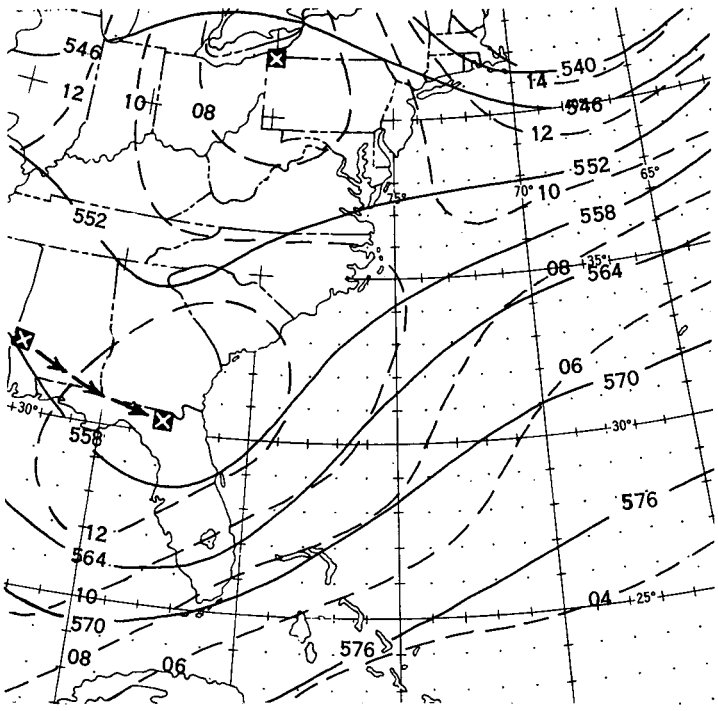

FIGURE 7.—500-mb. contours with isopleths of absolute vorticity for 0000 GMT, Feb. 7, 1968. Crosses mark centers of maximum and minimum vorticity. Arrows show 12-hr. track of vorticity maximum.

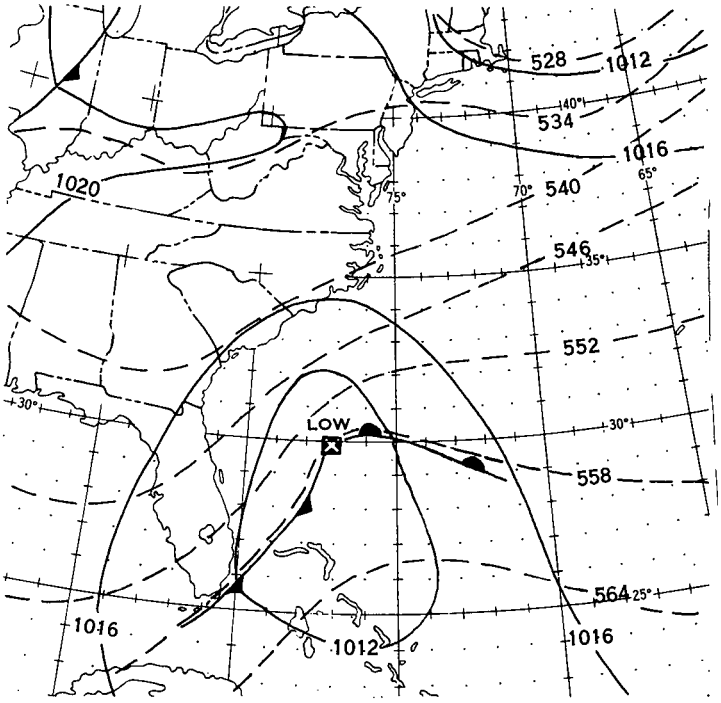

FIGURE 6.—Surface chart with 1000–500-mb. thickness for 0000 GMT, Feb. 7, 1968.

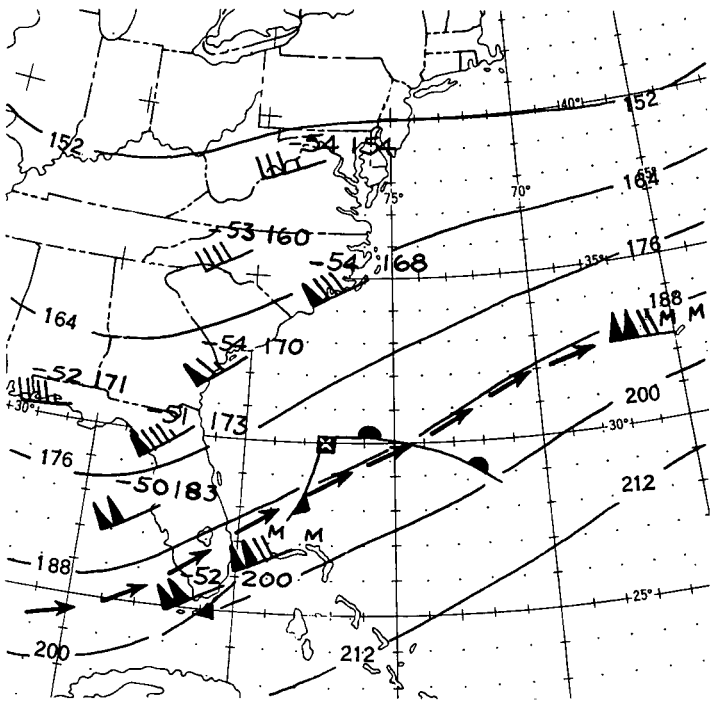

FIGURE 8.—200-mb. contours and jet stream for 0000 GMT, Feb. 7, 1968, with surface fronts superimposed.

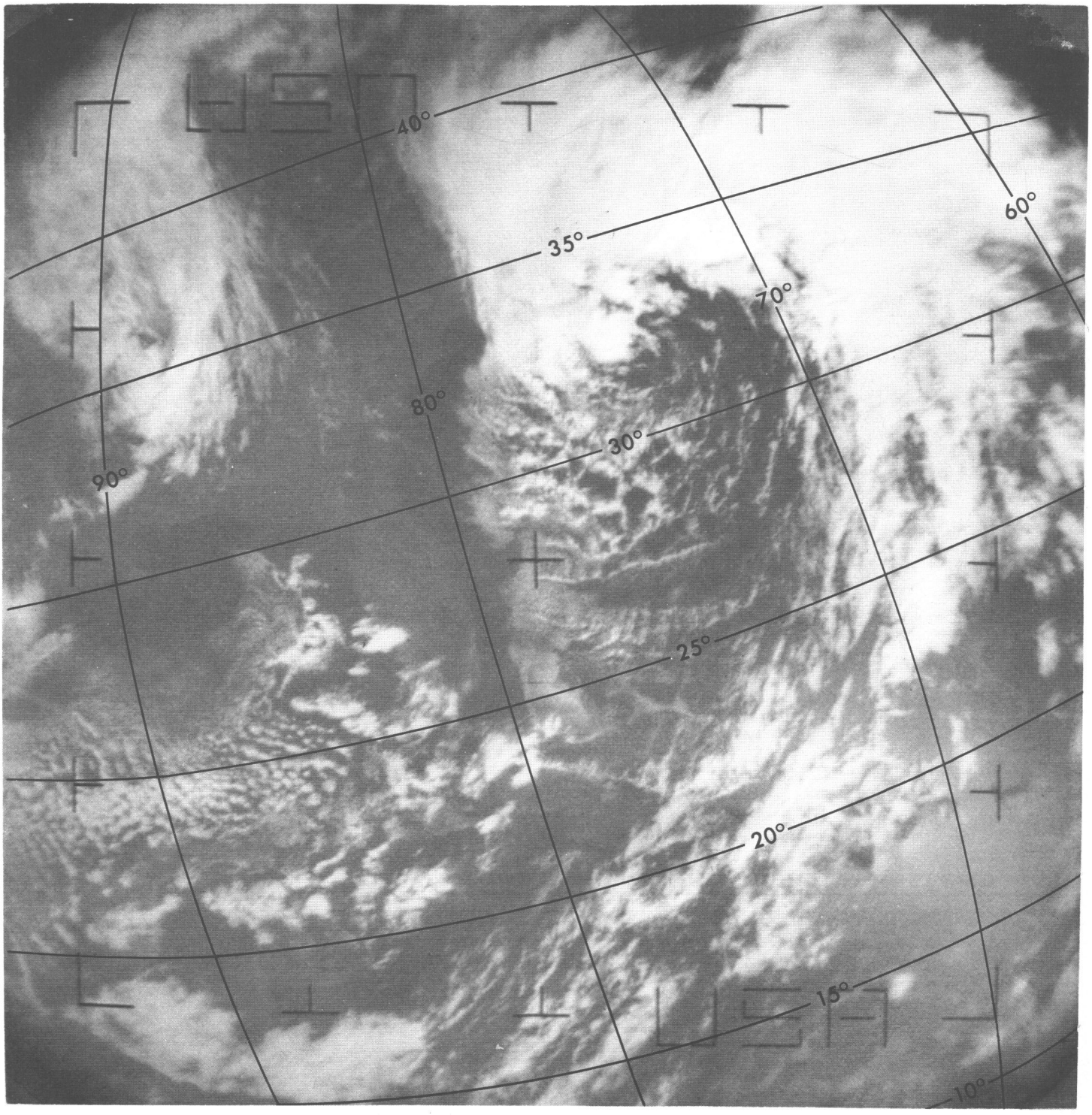

FIGURE 9.—ESSA-6 APT photograph of storm at 1500 GMT on Feb. 7, 1968.

33°N. and 75°W. at 1500 GMT) with considerable banding south of 32°N. in the southern semicircle of the cyclone.

3. RADAR OBSERVATIONS OF THE STORM

At 1445 GMT, February 7, the radar station at Cape Hatteras, N.C., began to observe a cyclonically curved line of precipitation in the northwestern portion of the area covered by its WSR-57M set. This line was moving from 120° at 15 kt. By 1540 GMT, the first line was still in evidence as well as two new lines exhibiting cyclonic curvature. At this time, an apparent circulation was detected southeast of the station.

In the light of an ESSA Research Flight Facility aircraft flight made at the 700-mb. level on February 7 and 8, some doubt is cast on the nature of this apparent

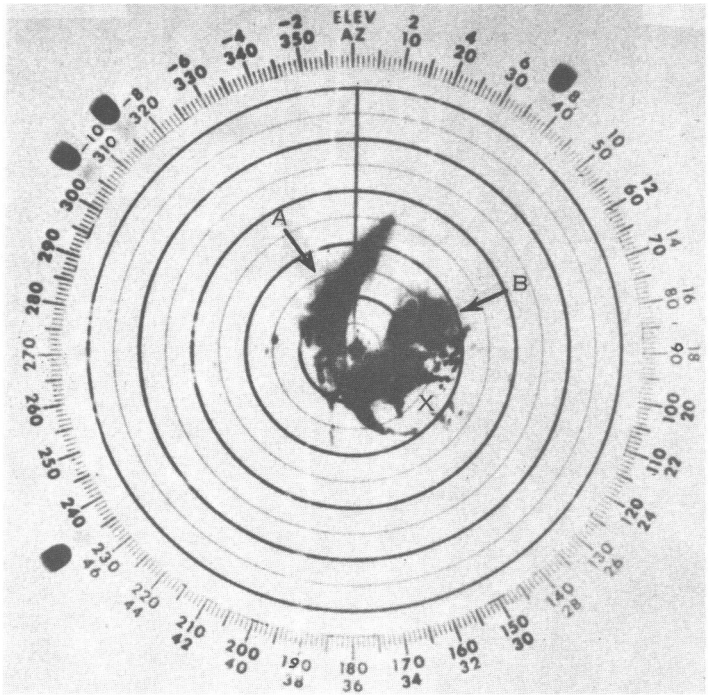

FIGURE 10.—Cape Hatteras WSR-57M radar presentation at 1650 GMT, Feb. 7, 1968. Range 250 n.mi., range circles 25 n.mi., long pulse, STC on. A and B indicate cyclonically curved bands. X marks apparent center.

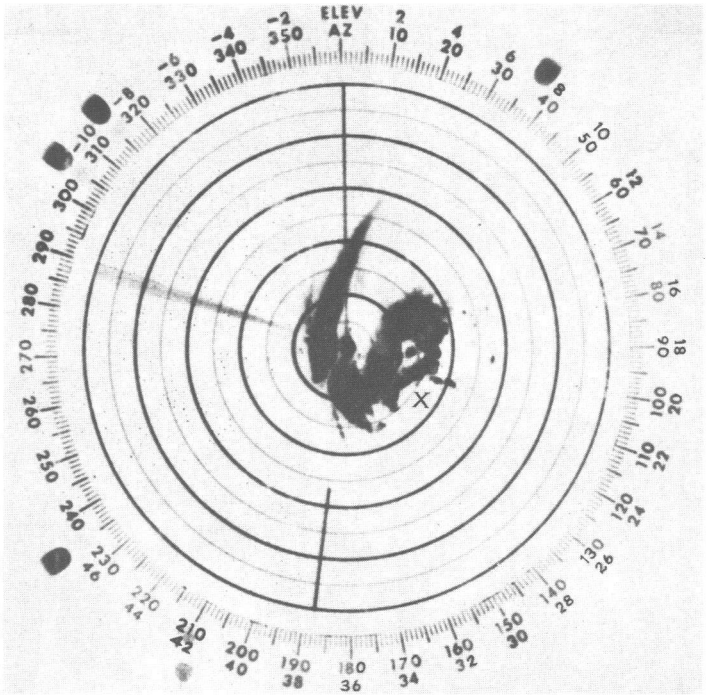

FIGURE 11.—Cape Hatteras radar presentation at 1745 GMT, Feb. 7, 1968. Range 250 n.mi., range circles 25 n.mi., long pulse, STC on. X marks apparent center.

center [1]. There is some possibility that the center detected by radar was an eddy embedded in the storm circulation. However, the flight of February 7 did not reach the vicinity of the track of the storm as indicated by radar until 2215 GMT at the earliest. This was over 2 hr. after the center was last discernible on radar. There is a high probability that the radar center was the real center of the storm, especially in light of subsequent aircraft observations indicating a relatively warm core present at 700 mb. on both February 7 and 8, with a center resembling a hurricane eye.

In a letter to the author, James Myers, Radar Meteorologist at the Cape Hatteras Weather Bureau Office, states that the WSR-57M used in these observations was operating in short pulse with a range of 125 n.mi. from 0240 GMT to 1640 GMT on February 7. After 1640 GMT, the set operated in long pulse with more transmitted energy and a 250-n.mi. range, and obtained a more accurate radar fix on the Low.

An apparent center with movement unknown was observed at 1640 GMT on a bearing of 133° at 86 n.mi. or near 34.3°N. and 74.2°W. As shown on the radar picture for 1650 GMT (fig. 10), this center was determined by a cyclonically curved line (A) in the northwest quadrant of the Low and cyclonically curved line (B) in the northeast quadrant. The lines were about 30 n.mi. wide, with a movement from 120° at 10 kt.

The 1745 GMT radar observation (fig. 11) showed an apparent center bearing 125° at 78 n.mi. or near 34.5°N.

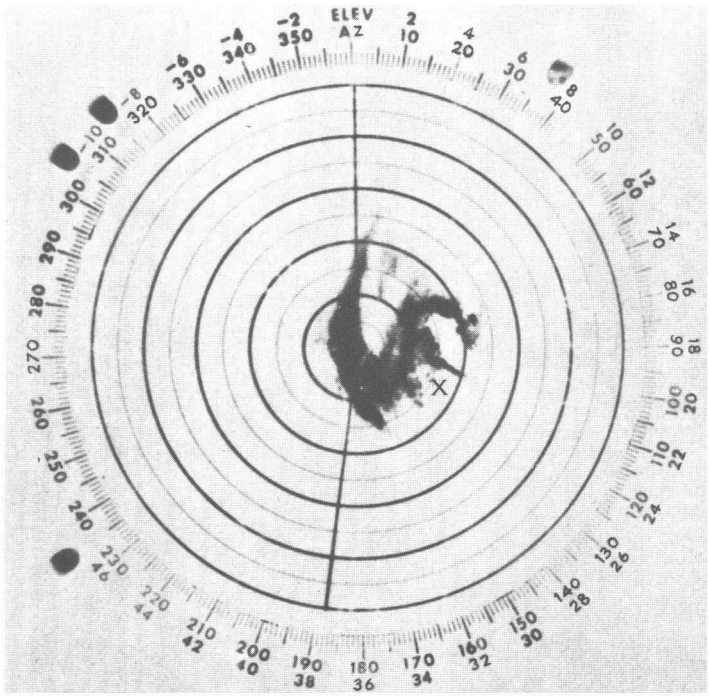

FIGURE 12.—Cape Hatteras radar presentation at 1840 GMT, Feb. 7, 1968. Range 250 n.mi., range circles 25 n.mi., long pulse, STC on. X marks apparent center.

and 74.2°W. It was moving from 178° at 18 kt. The center of the Low showed no precipitation, while the echoes presented a definite cyclonic pattern.

The 1840 GMT radar observation (fig. 12) continued to show an apparent center bearing at 111° at 67 n.mi. or

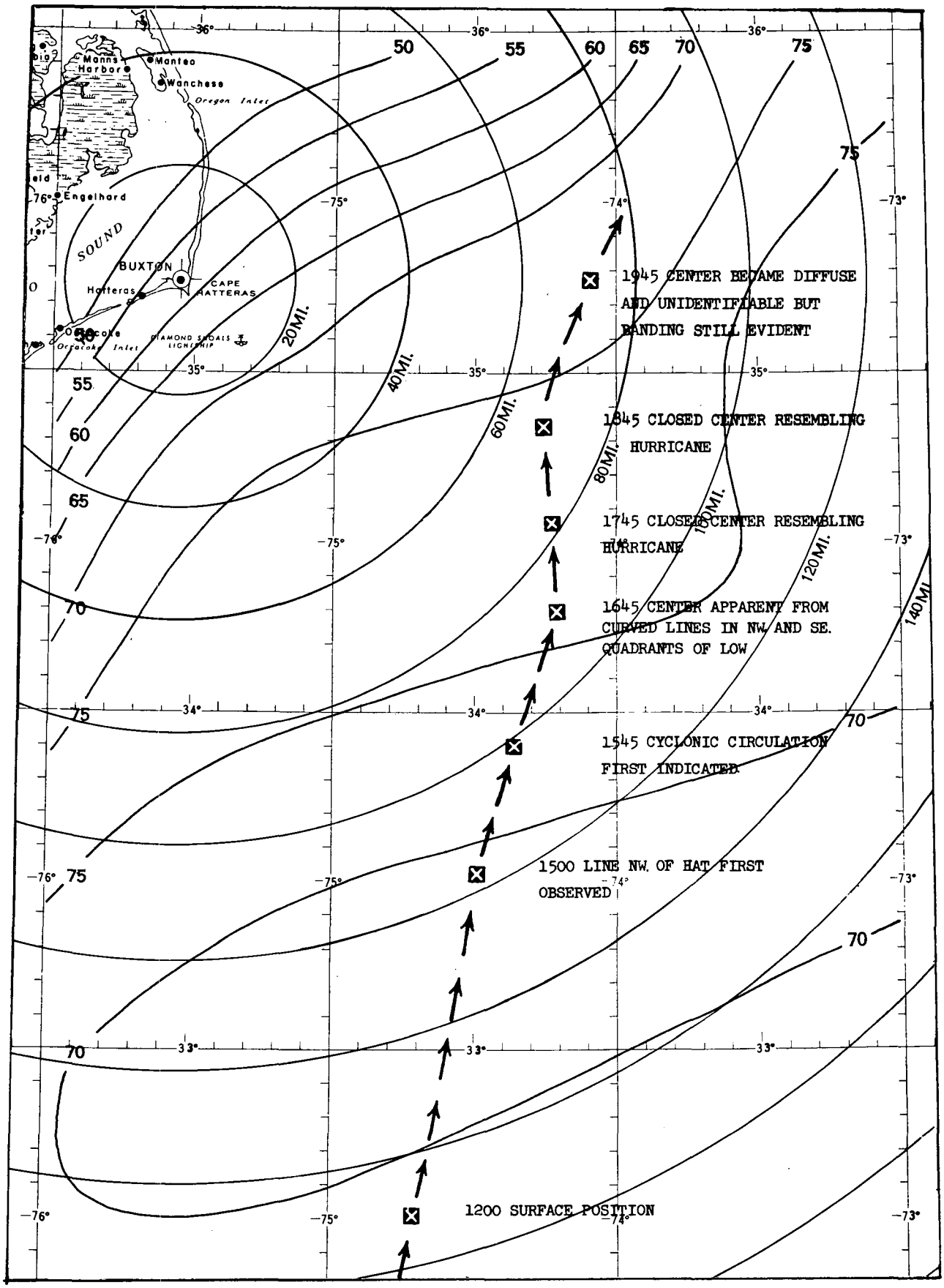

FIGURE 13.—Sea-surface temperatures (°F.) from U.S. Navy Fleet Weather Central, Norfolk, Va., for Feb. 7, 1968. Surface positions of Low (crosses) on February 7 with times (GMT) and radar observational remarks.

TABLE 1.—*Cape Hatteras, N.C., surface observations (aviation forms) from 1200 GMT through 2100 GMT, Feb. 7, 1968.*

1200Z	S E12⓪ 40⊕ 2R	077/42/42/0120/975
1300Z	E12⓪ 30⊕ 2RF	072/42/42/0120/973
1400Z	E10⓪ 30⊕ 2TRF	065/43/42/0120/971 T NE MVG EWD
1500	S E10⓪ 30⊕ 7R-	057/42/41/3622/968 TE20 722 172
1600Z	E10⓪ 30⊕ 7R-	048/43/40/3521/966
1700Z	E10⊕ 7R - -	039/43/40/3624/963
1800Z	E10⊕ 3/4 RF	019/41/41/3628 G41E/957/PRESFR
1900Z	S E10⓪ 30⊕ 3/4RF	023/39/39/3428 G 38E/959
2000Z	E10⊕ 3/4RS-F	022/37/37/3530 G38E/958 SB12
2100Z	E10⊕ 3/4R-S-F	023/35/35/3426 G34E/959 RE07B45

near 34.8°N. and 74.3°W., and moving from 178° at 18 kt. Three well-defined cyclonically curved bands were observed. These were from 20 to 50 n.mi. wide.

In his letter Mr. Myers states that during the hours between 1640 GMT and 1840 GMT the radar showed a closed center which resembled a tropical storm or hurricane (fig. 10–12). The center of the Low showed no precipitation, while there was a definite cyclonic pattern to the remainder of the echoes. It was possible to use a 15° spiral overlay and locate the center by this method also [2].

By 1940 GMT, the low center had become diffuse and unidentifiable but there was still a cyclonic pattern discernible in the echoes. A change of direction of movement of the lines had occurred with a movement from 220° at 10 kt. Banding continued through 2145 GMT with a movement from 210° at 10 kt.

The vertical extent of the precipitation echoes in the western quadrant of the storm was 6,000 to 8,000 ft. over and near land, gradually increasing to 14,000 ft. just west of the center. To the east of the center, maximum tops were consistently 18,000 to 20,000 ft.

The banding became most apparent on radar as the low center moved over sea-surface temperatures of 70°F. and greater. The best definition of the low center and the cyclonic banding correlated well with the highest water temperatures (fig. 13). In this respect some relationship to hurricane redefinition and/or intensification over a very warm water surface seems indicated [3].

Some weather observations taken at Cape Hatteras from 1200 GMT through 2100 GMT, February 7 (table 1), show an interesting correlation with the lines observed by radar. Moderate to heavy rain occurred as a line moved over the station between 1800 GMT and 1900 GMT (fig. 11, 12) indicating strong convergence in the lines and lesser convergence outside the lines much as in the spiral bands of hurricanes. Also, increased wind speeds with gusts were observed. Light rain with lower wind speeds were observed outside the lines (fig. 10 and table 1).

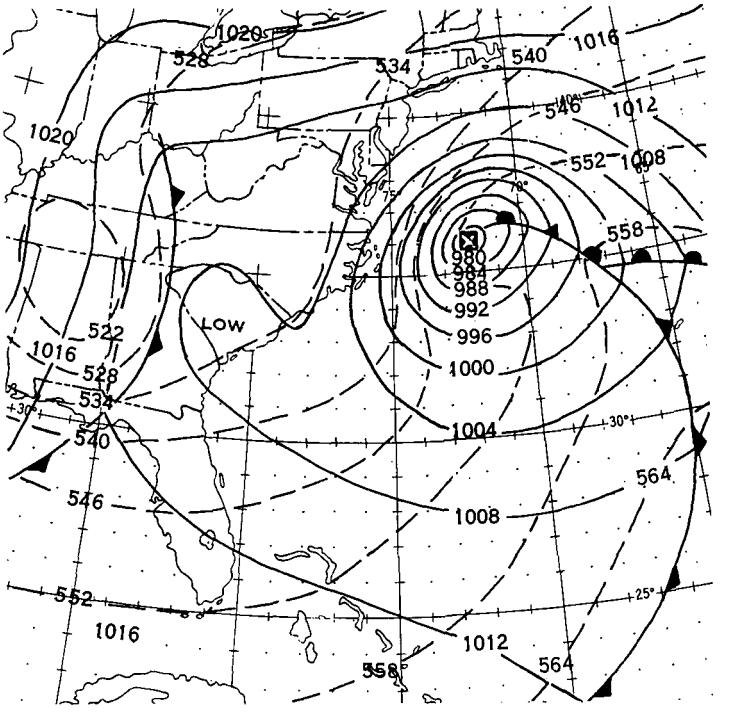

FIGURE 14.—Surface chart with 1000–500-mb. thickness lines for 0000 GMT, Feb. 8, 1968.

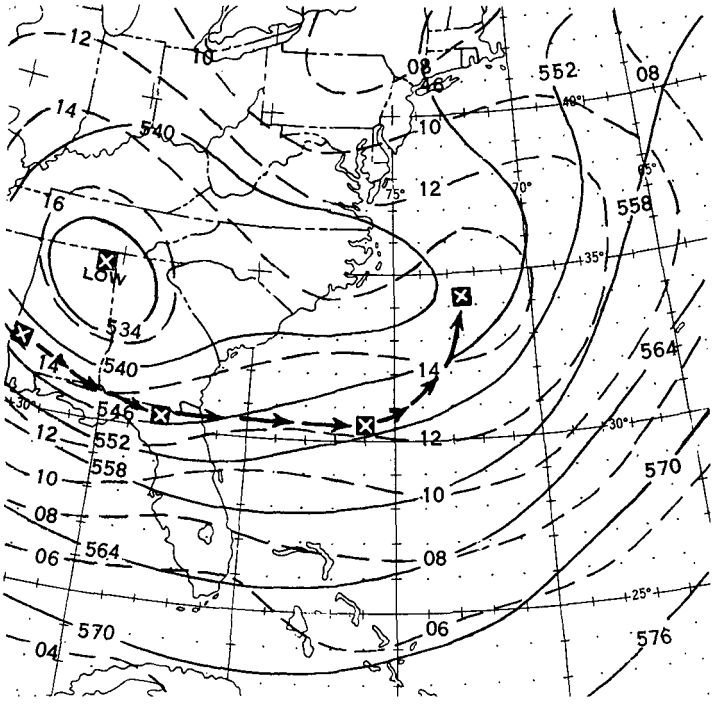

FIGURE 15.—500-mb. contours with isopleths of absolute vorticity for 0000 GMT, Feb. 8, 1968. Crosses mark centers of maximum vorticity. Arrows show 12-hr. track of vorticity maximum associated with surface Low.

4. LATER STAGES OF STORM DEVELOPMENT

The surface Low was located near 36°N. and 72°W. at 0000 GMT on February 8 (fig. 14). In the 12 hr. prior to

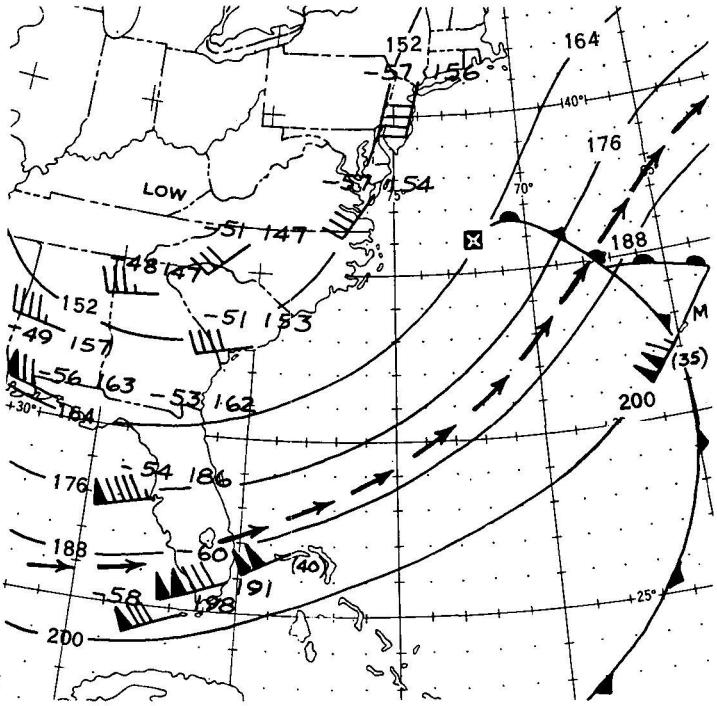

FIGURE 16.—200-mb. contours and jet stream for 0000 GMT, Feb. 8, 1968, with surface fronts superimposed.

this time, the surface Low had deepened another 17 mb. Ships near the center were reporting sustained winds of 65 kt. The 1000–500-mb. thickness field indicated a rapidly occluding cyclone (fig. 14).

Aloft the 500-mb. vorticity maximum had moved from near 31°N., 76°W., to approximately 34°N., 74°W. (fig. 15). Strong positive vorticity and warm air advection with significant upward vertical motion were indicated northeast of the surface Low.

Cloudiness had spread into southern New England and the coastal areas of Pennsylvania and New York State. High winds were reported at Cape Hatteras with 1.17 in. of rain being observed in the previous 6 hr. Snow was falling over eastern North Carolina and southeastern Virginia.

The upper tropospheric jet stream near 200 mb. was now located 4° to the southeast of the surface Low (fig. 16) as is normally the case in an occluded cyclone [4].

An interesting picture (fig. 17) was taken by ESSA 6 at 1359 GMT, February 8. The cloudless area in the cyclonic vortex near 40°N., 68°W., was apparently the center of the completely occluded storm located near 39°N., 69°W., at 1200 GMT on February 8. The resemblance of the cloud picture to a hurricane is remarkable. A daylight penetra-

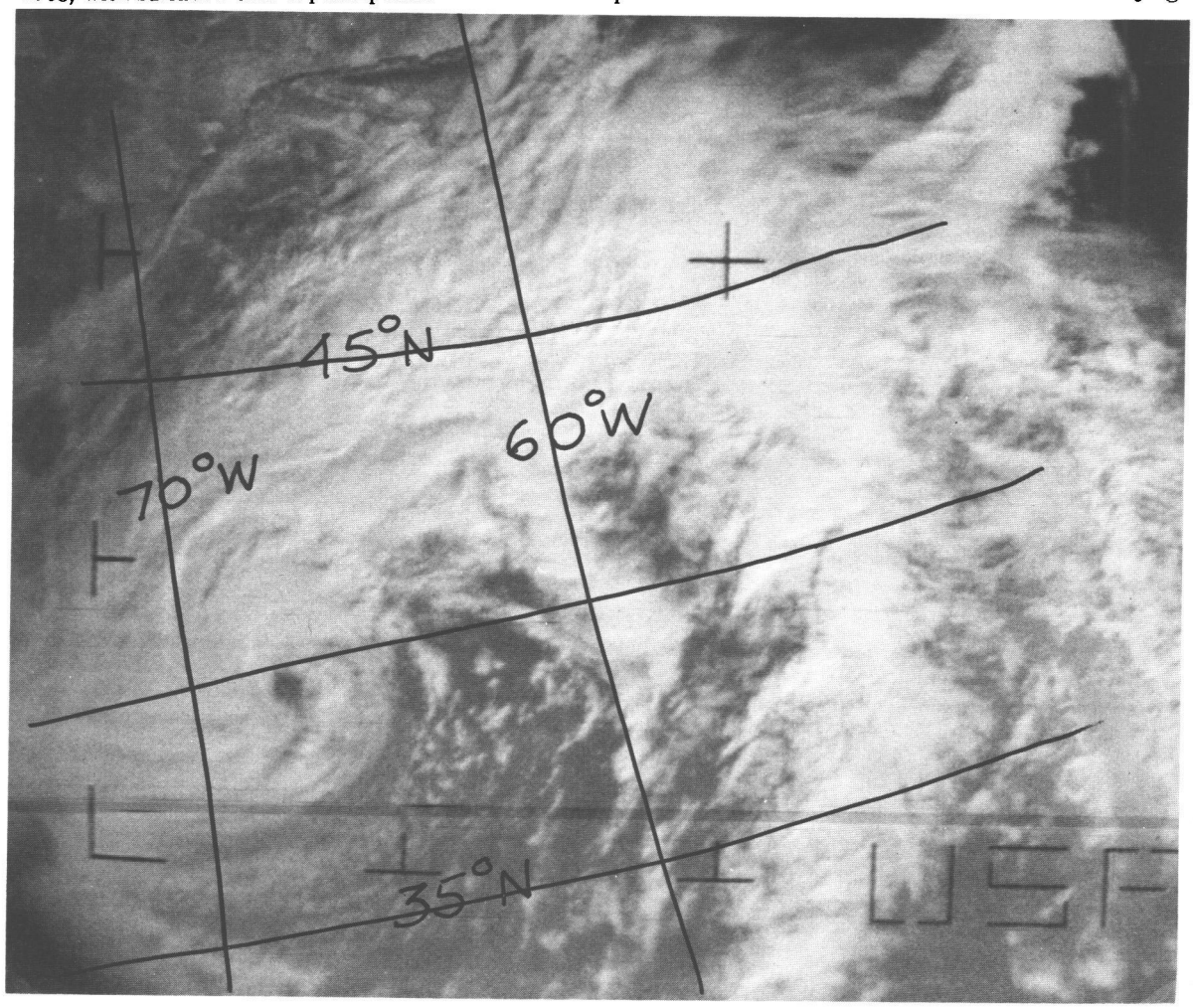

FIGURE 17.—ESSA-6 APT photograph of storm at 1359 GMT on Feb. 8, 1968.

tion of the storm center was made by an ESSA Research Flight Facility aircraft on February 8. The RFF crew stated the storm center had all the characteristics of a hurricane eye, lacking only the wall cloud.

5. SUMMARY AND CONCLUSION

These points stand out in this case of cyclogenesis. The surface Low originated in the subtropics. Its development was initiated as an eastward-moving upper air perturbation in the westerlies impinged on an incipient low level disturbance. A subtropical jet stream was present during the development. Continental polar and maritime tropical air masses only were involved. As the storm moved over the warm center of the Gulf Stream, for a short time the inner core appeared on radar to be similar to that of a tropical cyclone. This appearance became diffuse and unidentifiable as the Low apparently moved away from the warmest water of the Gulf Stream. There was a strong correlation between the radar lines and heavy rain and wind, much as in the spiral bands of hurricanes, etc. The storm continued to deepen and occlude, and, by the morning of February 8, presented on a satellite picture an appearance similar to a hurricane.

ACKNOWLEDGMENTS

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